SYNOPTIC PATTERNS FOR WET AND DRY TRADES ON THE ISLAND OF HAWAII

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ABSTRACT

An attempt is made to construct synoptic charts that will show readily recognizable differences in "dry trades" and "wet trades" on the island of Hawaii in the Hawaiian Islands. Also, correlations are attempted relating rainfall to the height of the freezing level and to air mass instability. It is concluded that there are several synoptic features that are distinctly different in the two cases.

1. INTRODUCTION

Forecasters in the Hawaiian Islands for years have been faced with the problem of deciding whether or not the trade winds are going to be dry or wet. Topography plays an extremely important role in island weather and mainly because of this feature many areas are semiarid while adjacent areas have yearly rainfall totals in excess of 400 inches [1]. But topography alone is not the rain-producing mechanism for it has been observed many times that surface trades of approximately equal strength and direction do not produce rainfall totals of anywhere near similar magnitudes.

There are several synoptic situations which tend to produce heavy rain. Easterly waves and troughs, shear lines, Kona Lows, tropical disturbances, and trade winds are the more notable examples. Trade winds occur 70–85 percent of the time [2], and although the other rain producers are a problem they occur relatively infrequently.

2. PLAN OF INVESTIGATION

In mid-October 1954 Project Shower commenced operation on the windward slopes of the Island of Hawaii and continued through the first week of December. Extensive observations during this period included four raobs daily and readings from a dense network of rain gages located mainly along the Saddle Road and Kulani Road (fig. 1). A complete description of Project Shower is found elsewhere [3]. Sugar plantations operating on the volcano slopes report rainfall amounts daily from their numerous fields. The additional gage readings during the project provided sufficient additional coverage so that daily isohyetal charts analyzed at that time are considered to be quite representative of the rainfall pattern as it actually occurred.

Because of the additional data available during Project Shower it was felt that an investigation of the daily surface and upper-air charts in this period, attempting to correlate 24-hour rainfall totals with synoptic patterns, would be worthwhile.

The total number of trade wind days during Project Shower was 34. Of this total, 10 days were chosen as being dry and 6 days as being wet. Dry days were considered as those days having a rainfall maximum of 0.3 inch or less on the windward sections of Hawaii; days with a maximum of 3 inches or more were chosen as wet days. A number of the dry days were absolutely dry and the rainfall on wet days ranged from 3 to 13 inches. The limits chosen are arbitrary but in general provide good separation from the more nearly normal days.

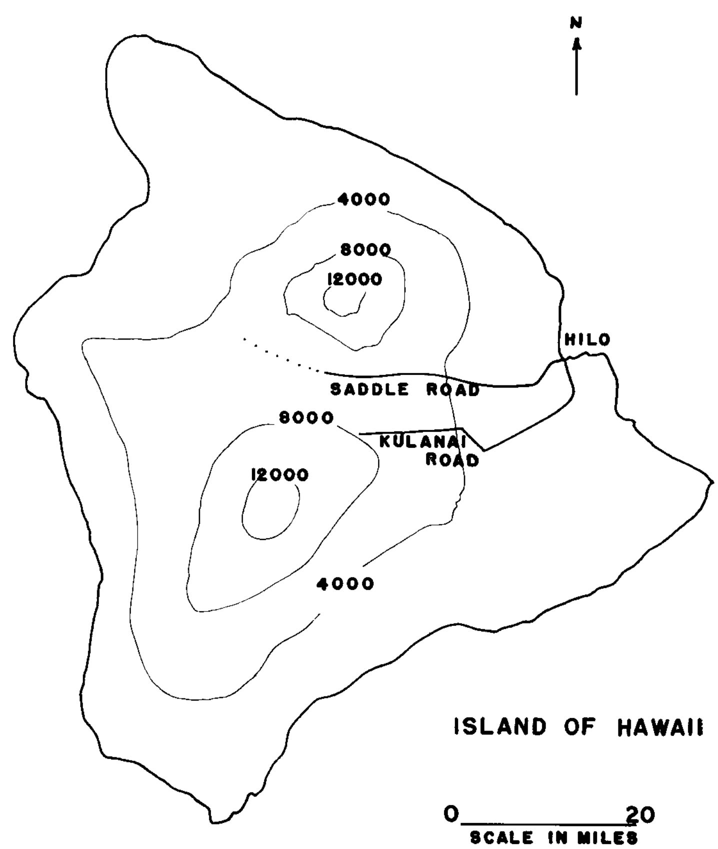

FIGURE 1.—Map of the Island of Hawaii (contours in feet).

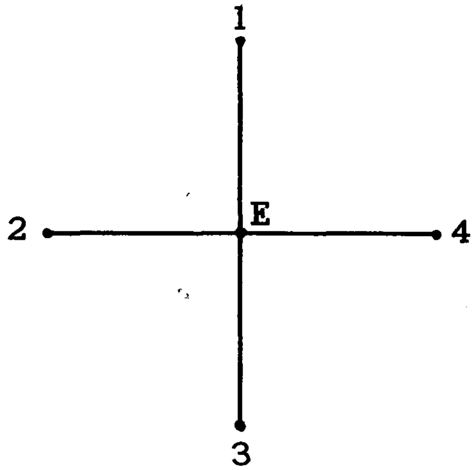

FIGURE 2.—Numbering of grid points for computation of relative vorticity at point E. (See equation (1)).

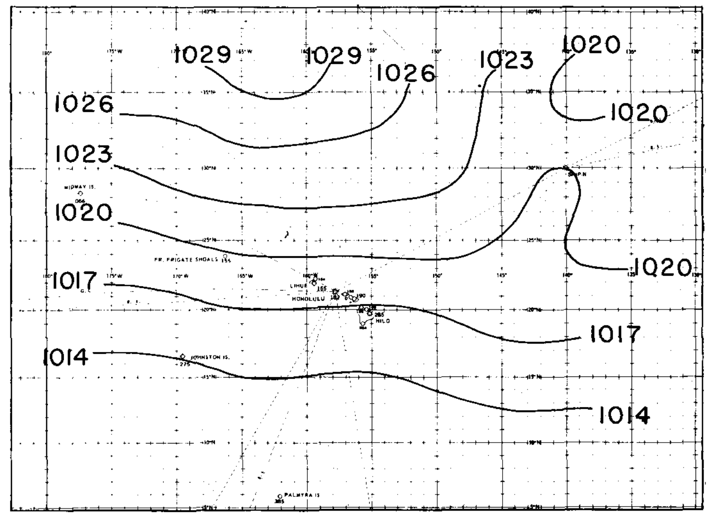

FIGURE 3.—Surface map depicting wet days (maximum rainfall $\geq$3 inches).

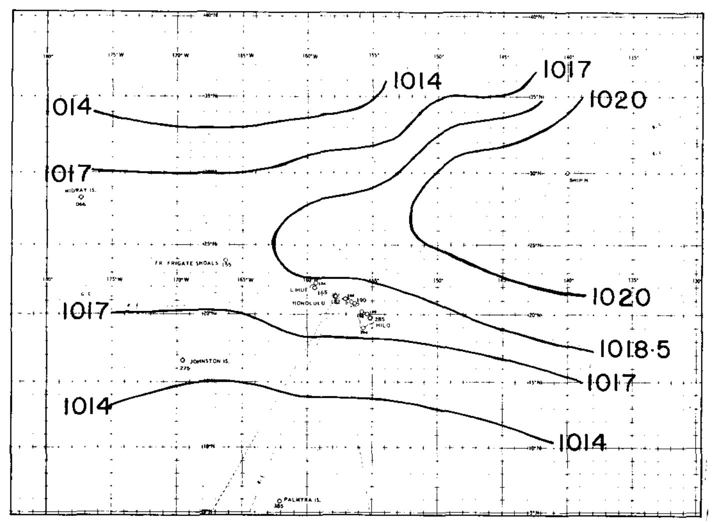

FIGURE 4.—Surface map depicting dry days (maximum rainfall $\lessapprox$0.3 inches).

The next step was to construct surface and upper-air charts that were most nearly typical of the wet and dry trade days. This was accomplished by averaging pressures and height values for all the dry days and then for all the wet days over an area bounded by latitudes 15° N. and 35° N. and longitudes 140° W. and 175° W. Heights and pressures were taken directly from the 1200 GMT synoptic charts at 5° intersections of latitude and longitude giving a total of 40 points. These values were then plotted and analyzed. Upon completion of the surface, 700-mb. and 500-mb. average charts, the 1000-mb. to 700-mb. and 1000-mb. to 500-mb. thickness patterns were analyzed.

A measure of the relative vorticity was computed in the Hawaiian Island area using

$$\zeta_E=\frac{4g}{fd^2}\,(\overline{z}-z_E) \tag{1}$$

where $\overline{z}=\frac{1}{4}(z_1+z_2+z_3+z_4)$ and the subscripts designate values at grid points as shown in figure 2. It was assumed that over a small area in these latitudes the term $4g/(fd^2)$ was almost constant so that $\zeta_E \propto \overline{z}-z_E$. Admittedly the geostrophic assumption implicit in the above is not entirely satisfactory at these latitudes. Nevertheless, it is felt the method does provide a measurement that is useful for comparison purposes. Although this is not a tool ordinarily available to the forecaster, the difference in the vorticity pattern for the wet and dry days is so striking it was felt that attention should be brought to that feature.

In an attempt to correlate rainfall amounts with upper-air soundings, the height of the freezing level and Showalter's [4] Stability Index were plotted against total rainfall. This was done for all days, not for just the wet and dry trade days.

3. RESULTS

The surface charts on wet and dry days (figs. 3 and 4) illustrate their major difference. On the dry chart the subtropical ridge is found to be a scant 300 miles north of the island chain with westerlies appearing north of 28° N. The wet chart shows the Pacific High well to the north and substantially stronger. This is in agreement with Solot and Haggard [5] who found that trade wind rainfall decreased as the east-west subtropical ridge came closer to the Islands. Another interesting difference is the location of the two Highs. During the dry trades the High is located close to Ocean Station N and on wet days it is found far to the north of the Islands. From the few cases studied it appeared that the dry type is usually quasi-stationary and the northern High is migratory.

Aloft on dry days the ridge slopes to the south so that at 500 mb. the ridge line lies almost through the Islands (figs. 5, 6). The wet chart is significantly different in

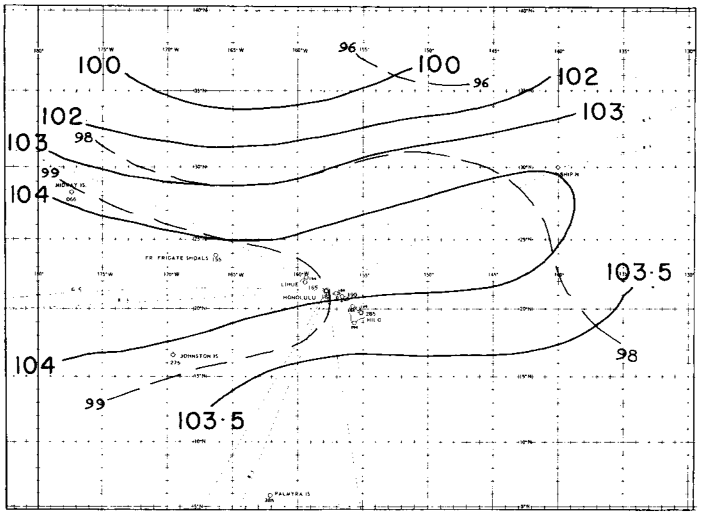

FIGURE 5.—For dry days: 700-mb. chart (solid lines) and 1000-mb. to 700-mb. thickness (dashed lines).

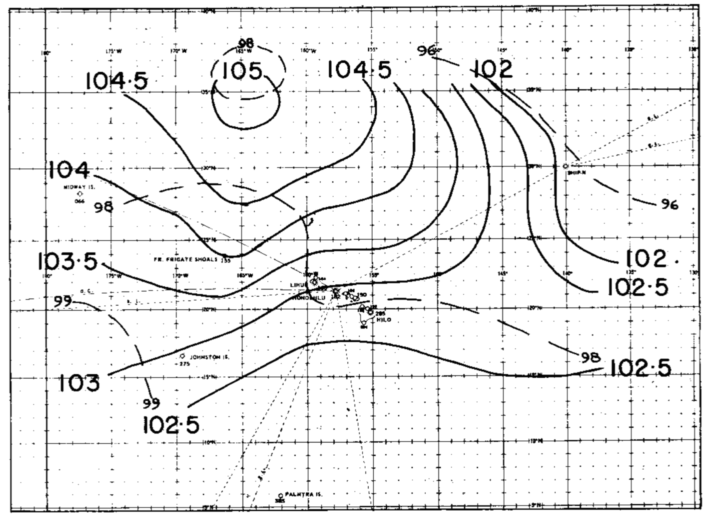

FIGURE 7.—For wet days: 700-mb. chart (solid lines) and 1000-mb. to 700-mb. thickness (dashed lines).

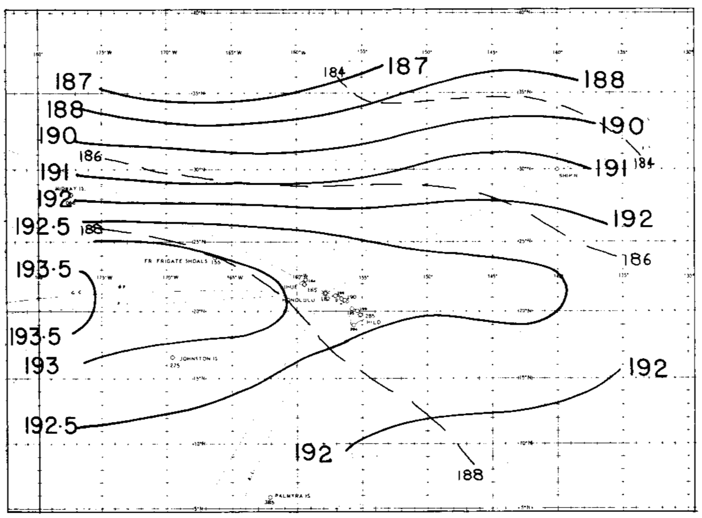

FIGURE 6.—For dry days: 500-mb. chart (solid lines) and 1000-mb. to 500-mb. thickness (dashed lines).

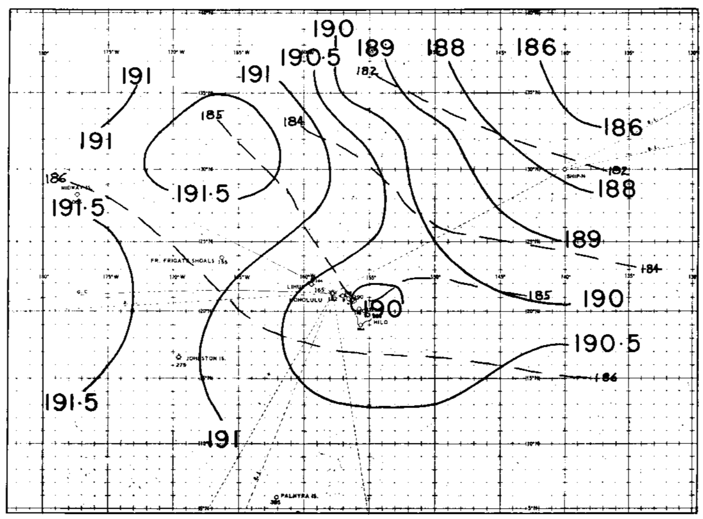

FIGURE 8.—For wet days: 500-mb. chart (solid lines) and 1000-mb. to 500-mb. thickness (dashed lines).

that the warm Highs are quite far to the north. At 700 mb. (fig. 7) weak trades still persist over the Islands, but at 500 mb. (fig. 8) a closed Low lies almost over the Islands.

The vorticity maximum centered over the Islands on wet days (fig. 9) differs widely from the anticyclonic vorticity found in the area on dry days (fig. 10).

It would be desirable to correlate air mass instability with trade showers in the Hawaiian Islands, but thus far attempts along these lines have not been successful mainly because weather conditions are so extremely variable. A series of showers may pass over the raob station during the raob run showing moist conditions on the sounding, but it is quite possible that there will be no more shower activity the rest of the day. The reverse is also true, of course. Lack of upper-air data upstream and this extremely variable shower condition have thus far proven to be formidable obstacles in the search for a consistent forecast tool. There are, however, some points of interest in this endeavor. The heavy rain situations generally had two features in common: (1) The freezing level fell below 12,500 feet, and (2) Showalter's Stability Index was generally less than +2, although three cases of extremely heavy rain occurred with higher values (fig. 11). It can be seen from the best fit curves that the stability index falls off rather sharply as the rainfall increases to 6 inches. It is also evident that the driest days have the highest freezing levels and it would appear from these few cases that wet days do not ordinarily occur when both the freezing level and the stability index are high. The height of the freezing level is a reasonably good indicator for it lies well above the 6,000- to 8,000-foot trade wind inversion and therefore is not influenced directly by the shower variability mentioned above.

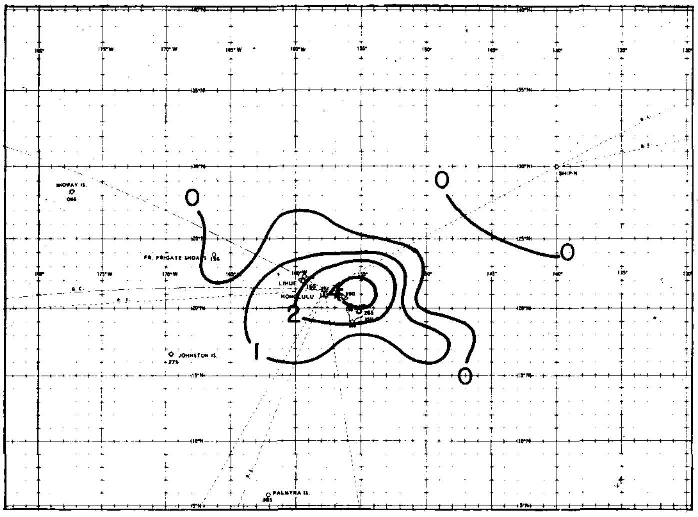

FIGURE 9.—Equivalent relative vorticity (in tens of feet) at 500 mb. for wet days.

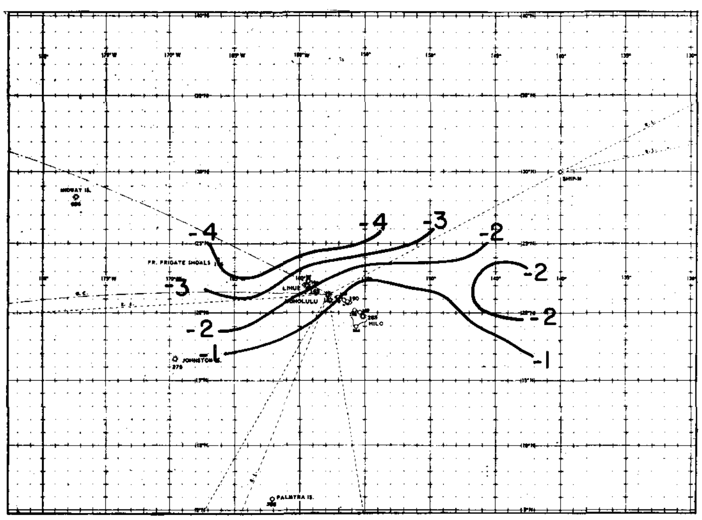

FIGURE 10.—Equivalent relative vorticity (in tens of feet) at 500 mb. for dry days.

4. CONCLUSION

Although the sampling is rather small the results from this study are encouraging. Our objective was to determine recognizable synoptic differences in the wet and dry trades, and there definitely are important differences, at least during the months studied. A similar study during the summer months should be made in an effort to delineate seasonal variation. Finally, the results have produced ideas on how the rainfall problem may be attacked objectively making statistical quantitative rainfall forecasts a definite possibility.

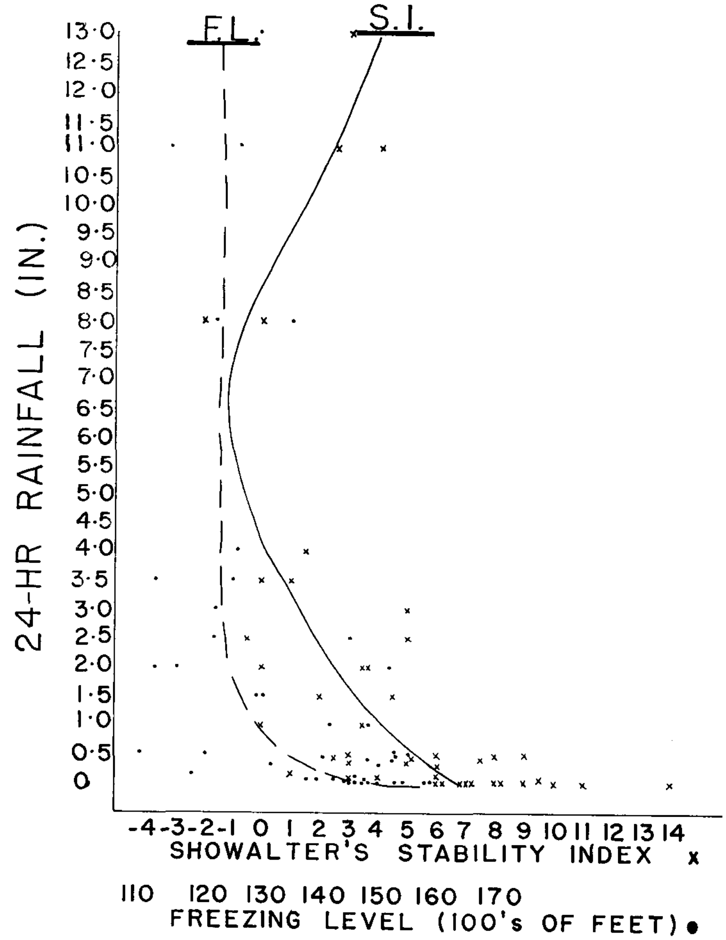

FIGURE 11.—24-hour rainfall (shown for all days) plotted against Showalter stability index (×) and height of freezing level (●).

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